URA and STD index for real-time orbit/clock/phase bias corrections at Shanghai Astronomical Observatory

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Introduction

Currently, International GNSS Service (IGS) analysis centers furnish global users with real-time orbit, clock, and phase bias corrections in either RTCM or IGS state space representation (SSR) format. Alongside these corrections, the User Range Accuracy (URA) is defined in SSR format to characterize the quality of satellite clock and radial orbit state parameters. However, the provision of URA information is absent across existing IGS analysis centers.

For real-time phase bias correction, only CNES and NRC provides that. Besides, considering the variability in accuracy among satellites, it is also imperative to furnish an index denoting the accuracy of it.

Tab. 1 Status of current IGS real-time products (As of 29/06 2024)

PRN	apm	bkg	cas	cne	gmv	gfz	nrc	whu
System	GREC	GRE	GREC	GREC	GRE	GREC	G	GREC
Interval	3	5	5	5	5	5	5	5
Orbit+Clock	√	√	√	√	√	√	√	√
Code Bias	×	√	×	√	√	√	√	×
Phase Bias	×	×	×	√	×	×	√	×
URA	×	×	×	×	×	×	×	×

Methodology

- URA for real-time orbit and clock

Since the constant biases of the orbits and clock errors do not affect PPP, but their variations do, we use the level of variation (STD) of the orbits and clock errors as the indicator of URA for float PPP users.

Using orbit and clock and fix the station coordinates in real-time PPP, we can calculate the post-fit residuals of the phase observations. By statistically analyzing the post-fit residuals of phase observations for all stations observing the same satellite, we can determine the URA.

$$URA^j = \sqrt{\frac{\sum_{i=1}^{n} V_i^j}{n}}$$

- STD index for real-time phase bias

Similarly, the post-fit residuals from the Phase Bias estimation can be used to represent the accuracy of the Phase Bias parameters.

$$STD_{WL}^j = \sqrt{\frac{\sum_{i=1}^{n} V_{i,WL}^j}{n}} \qquad STD_{NL}^j = \sqrt{\frac{\sum_{i=1}^{n} V_{i,NL}^j}{n}}$$

SHAO Real-time Products

By processing real-time GNSS data from around 130 MGEX stations distributed globally (Fig. 1), Shanghai Astronomical Observatory provides real-time products (SHA) with GREC orbit+clock+code bias+URA. G+E+BDS3 phase bias and their STD index are also included.

Table 2 summarizes the accuracy of the real-time GNSS products from SHAO over the one-month period from May 24 to June 23, 2024.

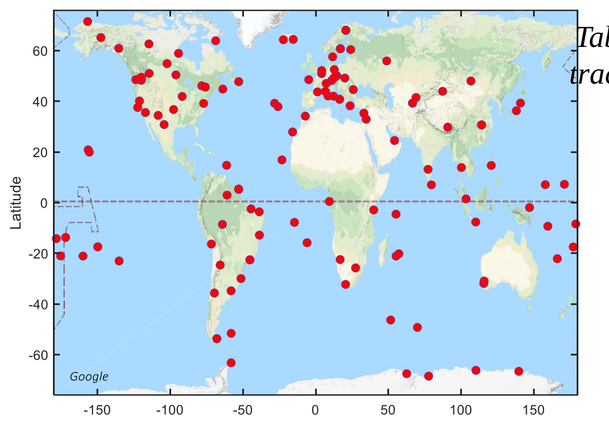

Fig. 2 Stations used

Tab. 2 Accuracy of SHA products in Cross-track(C), Along-track(A), Radial(R), and Clock(Clk) from 2024/05/24~06/23

System	C(m)	A(m)	R(m)	Clk(ns)
G	0.03	0.03	0.01	0.19
R	0.05	0.04	0.02	0.34
E	0.05	0.04	0.02	0.15
C3	0.07	0.07	0.03	0.24

SHA real-time products are broadcasted through Ntrip in RTCM format (Fig. 3). Additionally, the archived real-time products is also available at:
http://www.shao.ac.cn/shao_gnss_ac/products/realtime/

Fig. 3 SHA real-time products through Ntrip

- Caster：129.211.69.159
- Port：2101
- Mountpoint：SSRA01SHA0
- UserID：user1
- Password：test1

Benefit of URA for float PPP

Fig. 4 shows the URA values for SHA real-time orbit and clock over one week from May 23 to 29, 2024. At the same epoch, the URA values of different satellites can also vary significantly. For some satellites, the URA values may exceed 1 cm.

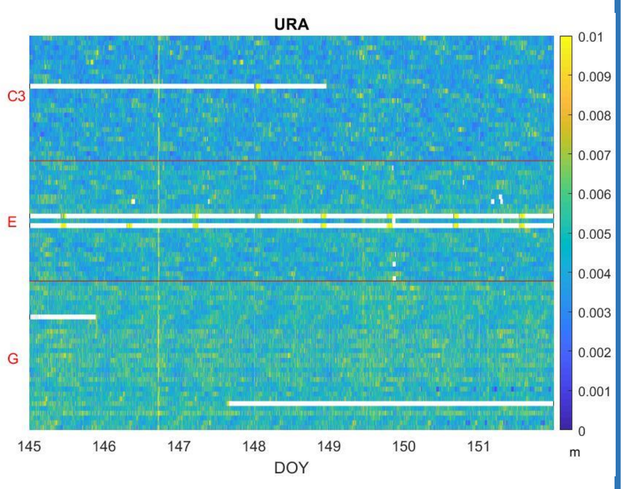

Fig. 4 URA values of SHA real-time products from May 23 to 29, 2024

After obtaining the URA information, users can use it for PPP. The stochastic model for positioning is as the right equation:

$$\begin{cases} \sigma_{obs,P}^2 = \sigma_{URA}^2 + \sigma_{code}^2(Ele) \\ \sigma_{obs,L}^2 = \sigma_{URA}^2 + \sigma_{phase}^2(Ele) \end{cases}$$

where $\sigma^2(Ele)$ is the elevation depended observation model.

Fifteen global distributed MGEX stations are used for float PPP validation (Fig. 5). As we can see, URA can enhance real-time PPP performance, the improvement is marginal due to the high accuracy of real-time orbit and clocks. The improvement in accuracy is mainly reflected in the convergence period.

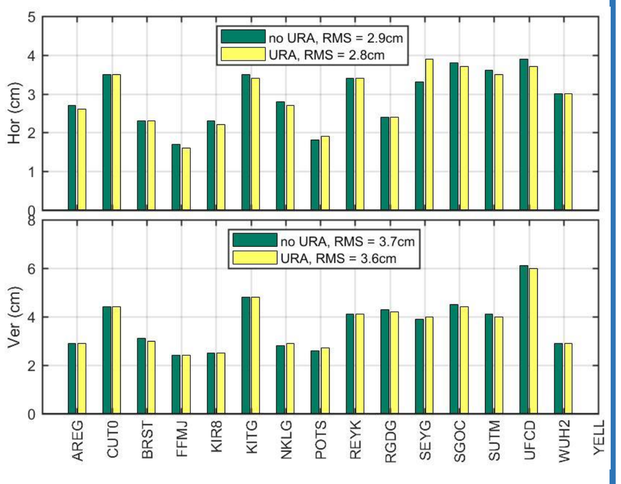

Fig. 5 PPP RMS with and without URA information

Benefit of STD index for PPP-AR

Fig. 4 shows the STD index for SHA real-time narrow-lane phase bias over one week from May 23 to 29, 2024. The STD value of BDS-3 is significantly worse than the other two systems, with a maximum difference exceeding 2 cm.

Similarly, the stochastic model for PPP-AR can be represented as the right equation :

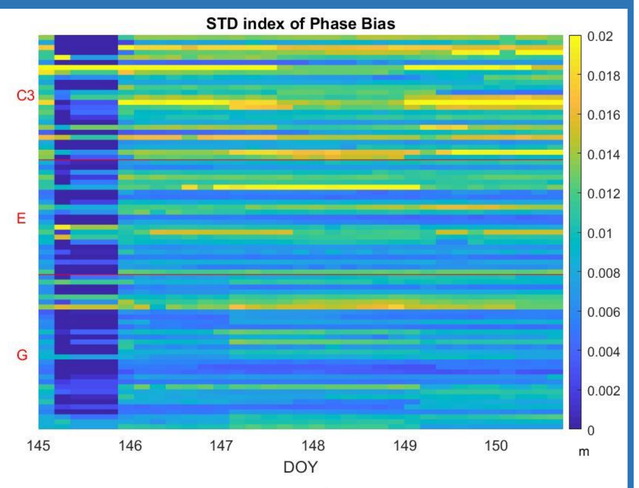

Fig. 6 STD index of SHA real-time phase bias from May 23 to 29, 2024

Fig 7. and 8 respectively show the hourly PPP-AR (re-initialized every hour) results at the FFMJ station without and with consideration of STD index for phase bias.

$$\begin{cases} \sigma_{obs,P}^2 = \sigma_{PC}^2 + \sigma_{URA}^2 \\ \sigma_{obs,L}^2 = \sigma_{LC}^2 + \sigma_{NL}^2 \end{cases}$$

Fig. 7 Hourly PPP-AR without (Left) and with (Right) the consideration of STD index for phase bias

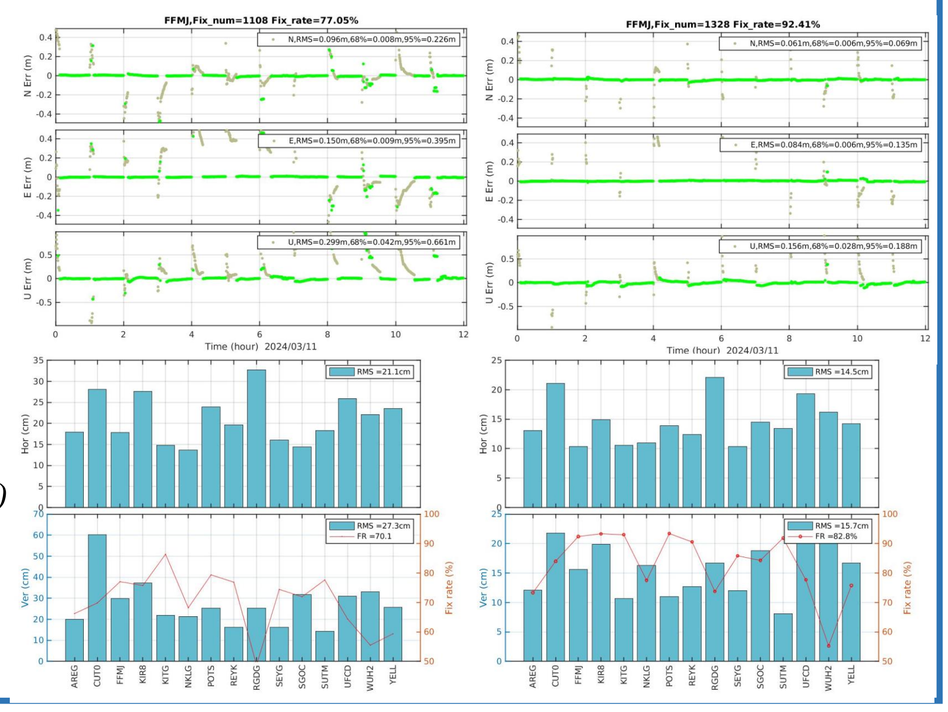

Fig. 8 RMS and Fix Rate (FR) of hourly PPP-AR without (Left) and with (Right) the consideration of STD index for phase bias